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Watershed Effects On The Value Of Marshes To Fisheries

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Abstract

Watershed size and rainfall patterns are among the factors that influence the extent to which fishery species use estuarine marshes as nurseries. We examined three Texas bays with different watershed characteristics to determine how marsh use by fishery species was affected. In each bay, we measured densities of aquatic fauna on marsh surfaces at sites located along the salinity gradient during seasonal periods of varying rainfall. Fishery species collected were transient juveniles of brown shrimp, white shrimp, spotted seatrout, southern flounder, red drum, and others. The largest bay with the largest watershed was Galveston Bay where, due to a relatively high river inflow rate and a large inlet from the Gulf of Mexico, a steep salinity gradient always persisted. During periods of high or low rainfall, the gradient was translocated but it was never eliminated. Mesohaline and polyhaline marshes of the middle and lower Galveston Bay were continuously used by fishery juveniles, whereas the oligohaline marshes of the upper bay were only intermittently used. By comparison, San Antonio Bay is small in size and has a large watershed. High rainfall often caused the salinity gradient in the bay to be virtually eliminated. Marsh use by most of the fishery species in San Antonio Bay was inversely related to the river flow and directly related to salinity. Gulf menhaden was the only exception where utilization was positively related with river flow. Lavaca Bay was also small in size and possessed a small watershed. A dam situated about 10 km above the river mouth further restricted river inflow. High salinities in this bay often extended onto the delta and high rainfall periods had little lasting effect on lowering salinity. The fishery species in Lavaca Bay used marshes throughout the bay, including those of the delta, extensively and often. As with the other bays, extended intervals of mesohaline and polyhaline salinities promoted the use of marshes by fishery animals. Persistent oligohaline conditions, on the other hand, depressed the use of marshes by fishery species in all three systems. We conclude that fishery production is least stable in small bays with large watersheds and that large bays with large mesohaline zones are most productive.

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Introduction

Production of estuarine dependent fisheries has been associated with the size and functional value of wetlands as nurseries (Boesch and Turner 1984; Minello and Zimmerman 1991) and with freshwater inflow (Gunter 1967; Armstrong 1982; Deegan et al. 1986; Matthews and Mueller 1987; Turek et al. 1987). In general, more wetland area (Turner 1977) and greater freshwater inflow (Armstrong 1982; Matthews and Mueller 1987) have been equated with higher fishery yields. Yet freshwater inflow and nursery utilization are often not compatible and their interactions can cancel each other for consumers. For example, low salinity thresholds of estuarine species are known (Kinne 1963; Zien-Eldin and Renaud 1986) and they limit the degree of utilization of wetland nurseries, regardless of the area available. Low freshwater inflow may also temporarily expand utilization into wetland habitats such as deltas which normally are unavailable. Geomorphologic features, such as size of an estuary in relation to its watershed, together with regional precipitation, may greatly control utilization characteristics of an estuary and thus control secondary production. Such area-wide effects on estuarine dependent fisheries are not well understood and only recently have come under scrutiny.

Our paper examines the use of Texas estuarine marshes by commercially important crustaceans and fishes in relation to salinity structure. Specifically, we discuss how the nursery use of marshes by fishery species is affected by the relationship of salinity to estuary and water shed size.

Methods

Three bays of the middle and upper Texas coast were compared for marsh utilization in relation to salinity. Information on Galveston Bay, the largest estuary in Texas, and two smaller bays, Lavaca Bay and San Antonio Bay, were obtained from Diener (1979) and Orlando Jr. et al. (1991) to establish the relationship between bay area and watershed size. Marsh nursery utilization was measured directly by sampling faunal abundances in the field. In this paper, we present Galveston Bay data that represent relationships between faunal distributions and salinity for all three bays.

To compare densities of fishes and decapod crustaceans in marshes along estuarine gradients in the bays, drop trap sampling, as described in Zimmerman et al. (1984), was used. This method employed a large cylindrical sampler (1.8 m dia.) dropped from a boom in front of a skiff to entrap shrimps, crabs and small fishes. Dermersal and nektonic fauna were collected and counted, yielding abundance of organisms per unit area, after water was pumped out of the sampler. In Galveston Bay, six marsh sites were chosen along the salinity gradient, two in each the upper (oligohaline), middle (mesohaline) and lower (polyhaline) zones of the bay (Zimmerman et al. 1990c). Four replicate drop samples were taken at each marsh site during spring, summer and fall of 1987.

The two smaller bays were sampled using the same technique, but over different temporal and spatial scales. Lavaca Bay was sampled at six marsh sites along the estuarine gradient in the fall of 1985 and again in the spring and summer of 1986 (Zimmerman et al. 1990a). San Antonio Bay was sampled during the spring and fall at three marsh sites located along the estuarine gradient beginning in the fall of 1986 and extending to the spring of 1989. The results on faunal abundances for these bays are reported elsewhere (Zimmerman et al. 1990a, b).

We used ANOVAs and a GLM contrasting procedure to test for differences (at the 0.05 alpha level) in mean densities of fauna among marshes along each estuarine gradient. In this paper, we report data for all fishes, all decapods, game fishes (spotted seatrout, southern flounder and red drum) and brown shrimp of Galveston Bay.

Results

The salinity gradient in Galveston Bay, the largest bay (1,360 km^2) with the largest watershed (63,455 km^2), was consistently present and always represented by oligohaline (0.5 to 5 ppt), mesohaline (5 to 18 ppt) and polyhaline (18 to 30 ppt) zones. Areal relationships among these zones changed seasonally (Fig. 1), but none of the zones ever disappeared entirely. The salinity gradient in San Antonio Bay, a small bay (530 km^2) with a relatively large watershed (28,200 km^2), varied mainly annually and was highly dependent upon riverine inflow. During periods when river flows were high, the salinity gradient was essentially eliminated and most of the bay became oligohaline (Fig. 2). In Lavaca Bay, a small bay (210 km^2) with a correspondingly small watershed (5,983 km^2), the salinity structure was dominated by tidal water from the Gulf of Mexico. The river delta in the upper bay was often polyhaline. Flood periods with high river flow caused salinity to be lowered radically, but only in short-term pulses (Fig. 3). Higher salinity usually returned within a period of a few weeks (Zimmerman et al. 1990a).

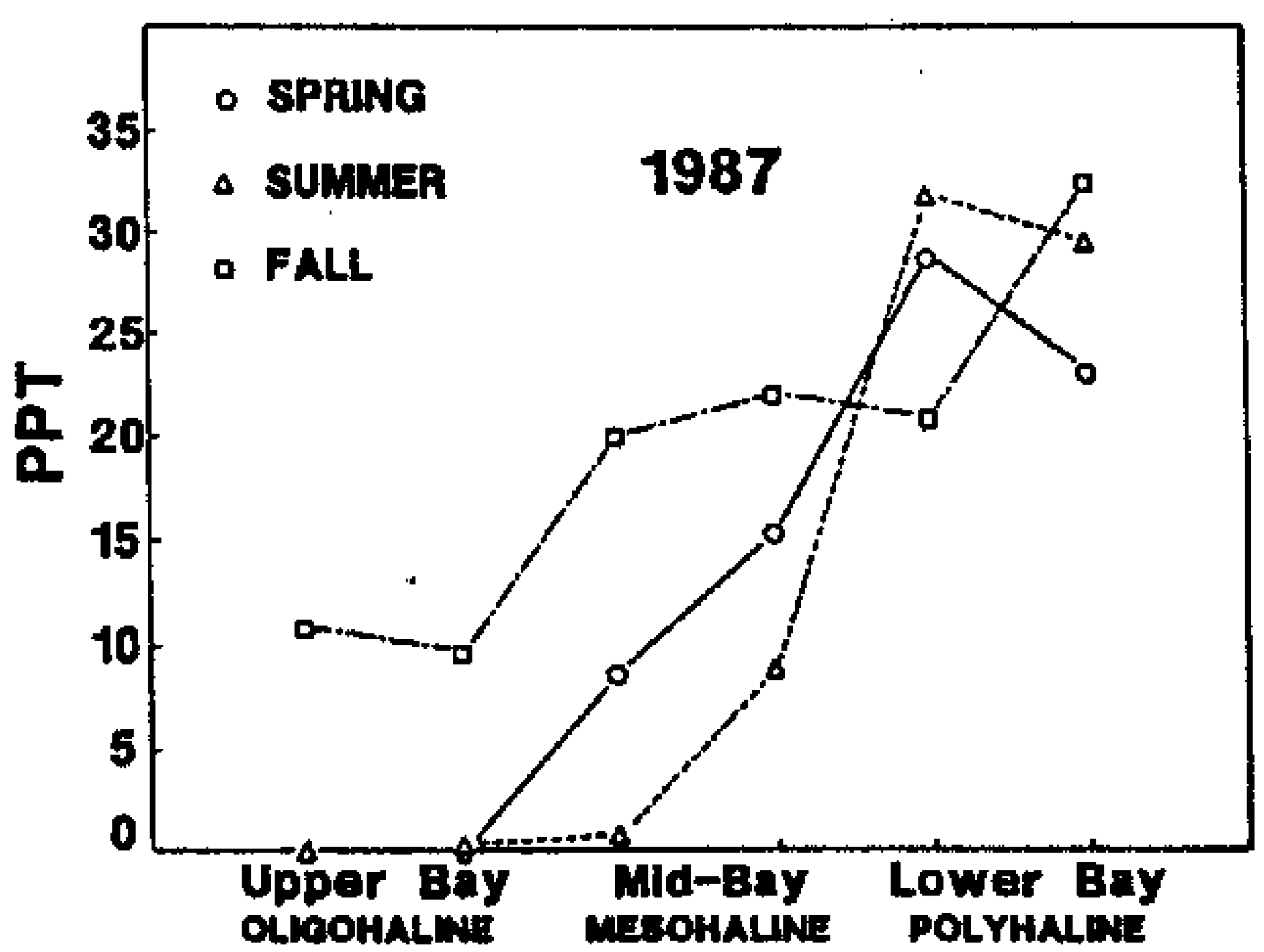

Figure 1. Seasonal salinities along the estuarine gradient in Galveston Bay.

Differences in salinity characteristics between the bays were related to ratios of watershed to bay area. San Antonio Bay was the freshest system with 53.2 km^2 of watershed for each km^2 of bay. Lavaca Bay was the most saline with 28.5:1 km^2 and Galveston Bay was intermediate with 46.6:1 km^2 watershed to bay area.

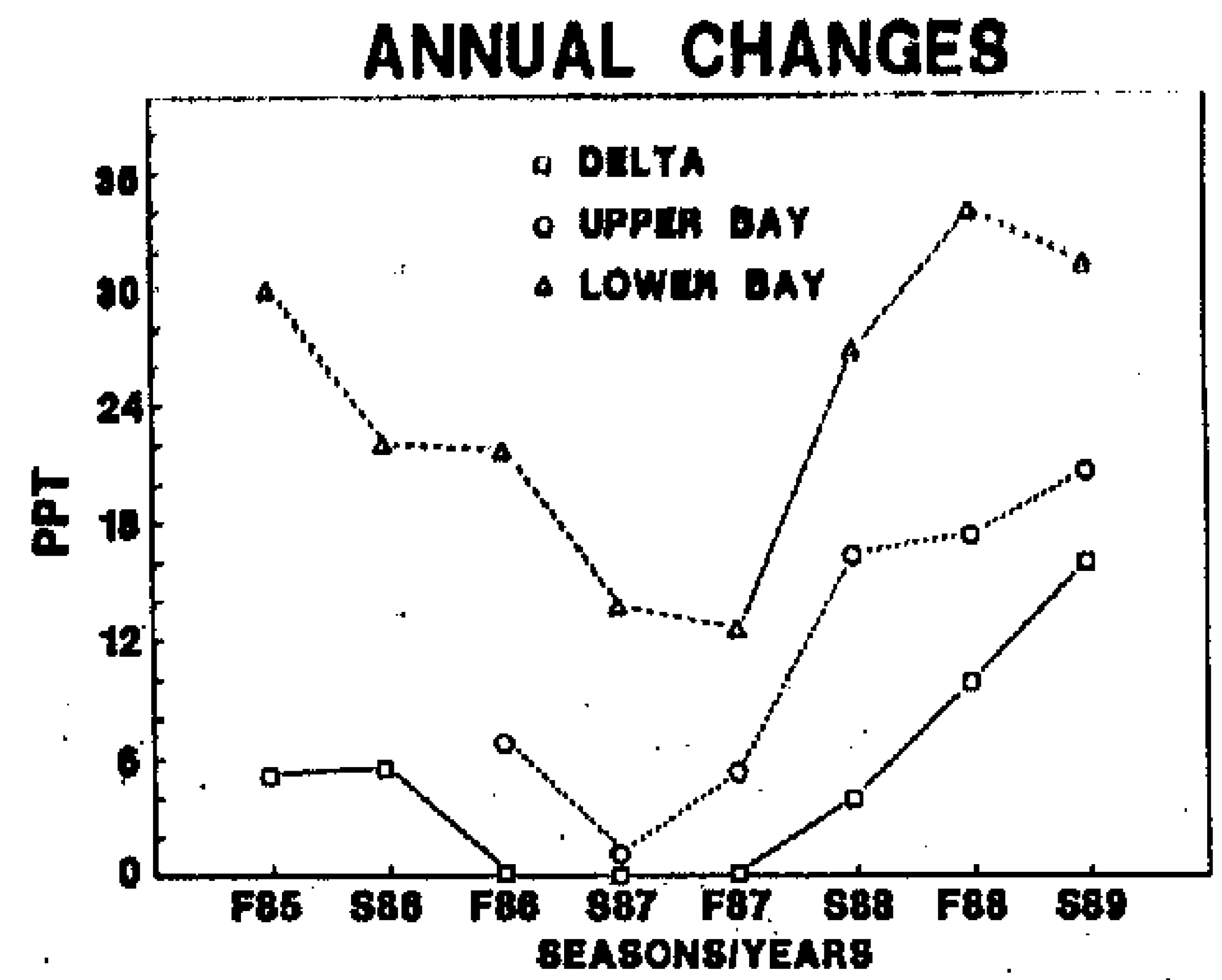

Figure 2. Annual changes in salinity along the estuarine gradient in San Antonio Bay from the fall (F) of 1986 to the spring (S) of 1989.

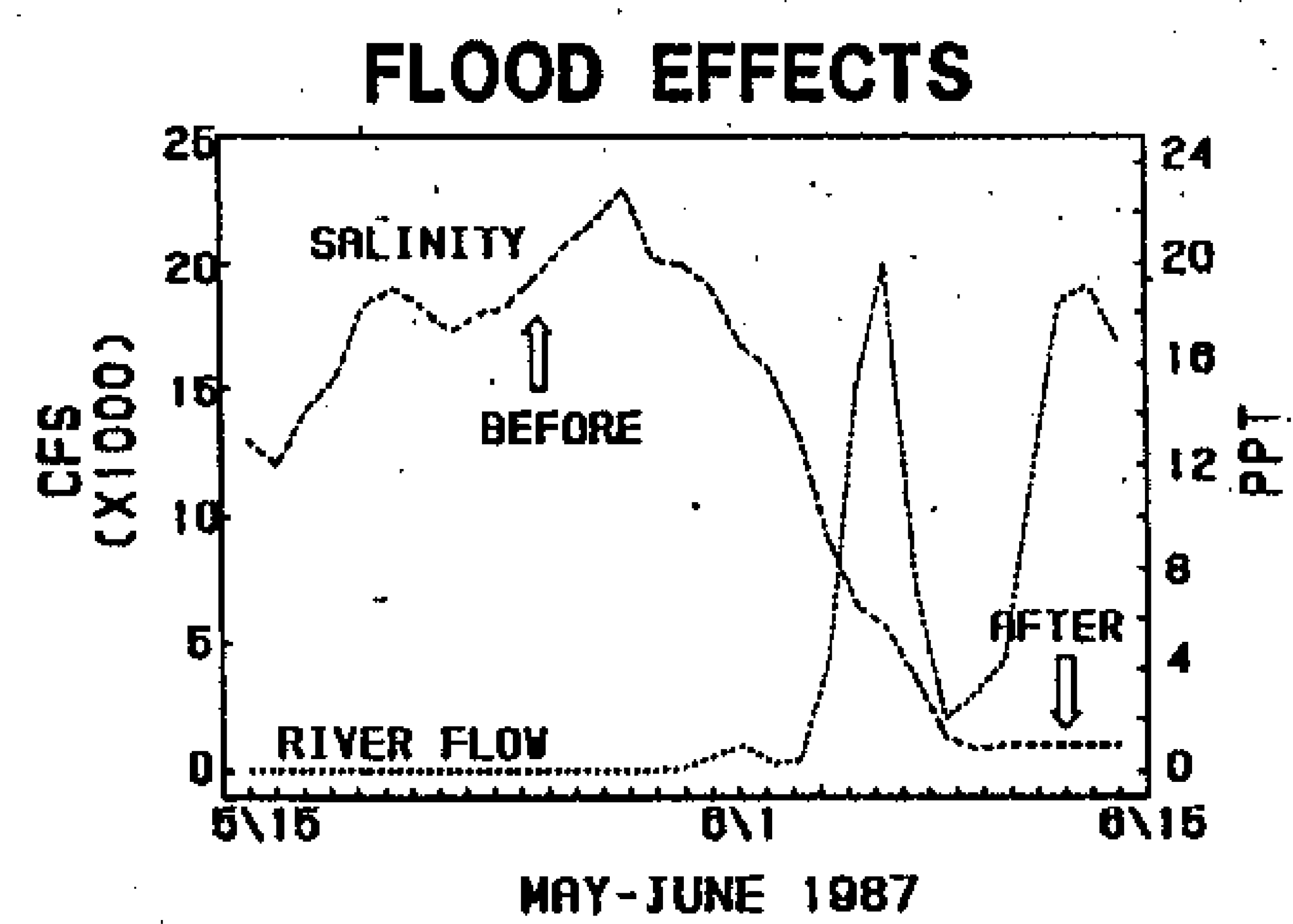

Figure 3. Rapid decline in salinity, from polyhaline to oligohaline, in upper Lavaca Bay, Texas, following a large scale flood event in May and June of 1987.

Overall fish densities were significantly higher (ANOVA planned contrast; P >0.05) in mesohaline marshes compared to oligohaline and polyhaline marshes of Galveston Bay (Fig. 4). For game fishes, mesohaline and polyhaline marshes had significantly higher abundances than oligohaline marshes, (Fig. 5).

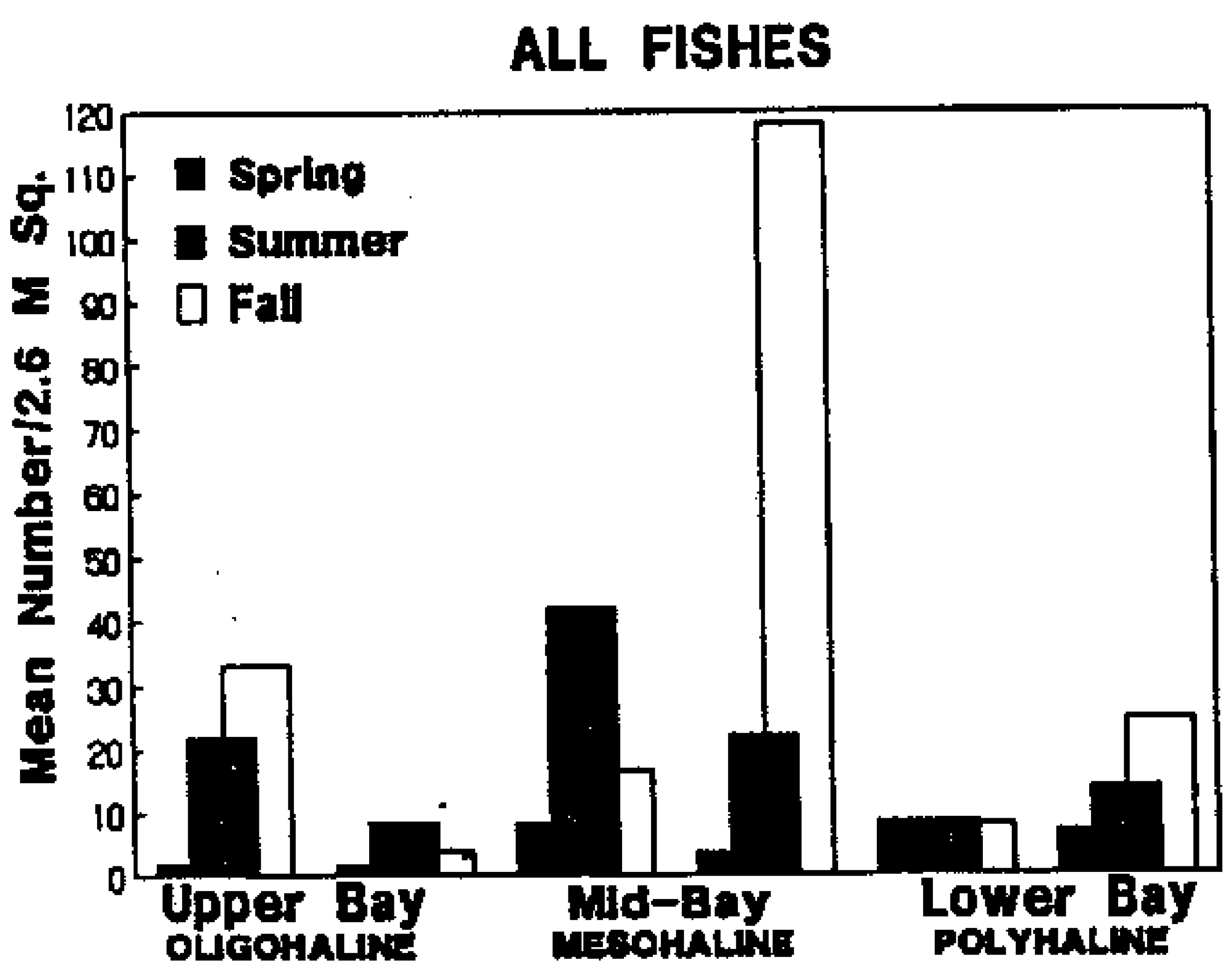

Figure 4. Densities of fishes in marshes distributed along the salinity gradient in Galveston Bay during spring, summer and fall seasons of 1987.

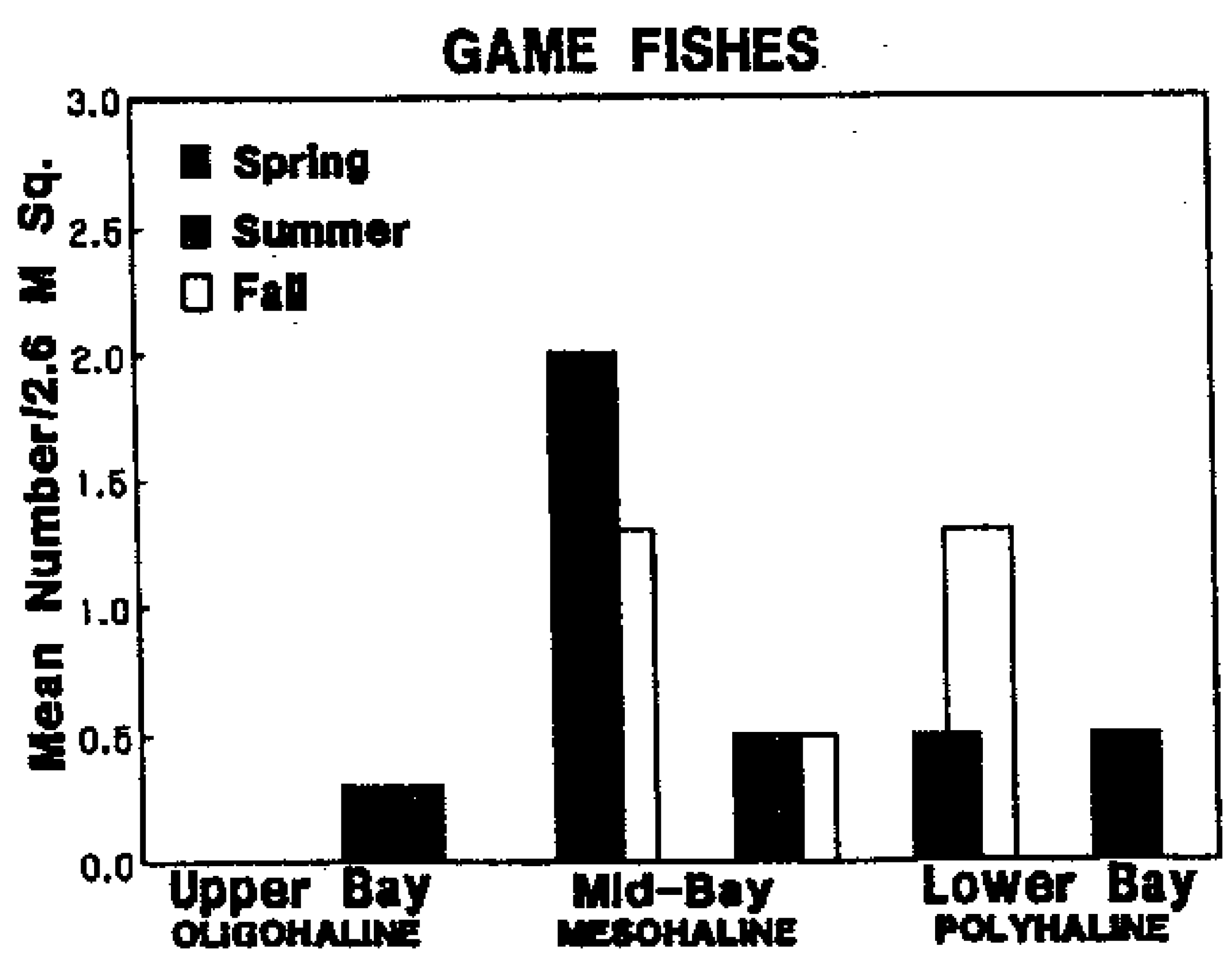

Figure 5. Densities of game fishes (spotted seatrout, southern flounder and red drum) in marshes along the salinity gradient in Galveston Bay during 1987.

Overall densities of decapod crustaceans, like fishes, were significantly higher (ANOVA planned contrast; P>0.05) in mesohaline marshes of Galveston Bay (Fig. 6). Among the decapods, penaeid shrimps were significantly more abundant in polyhaline and mesohaline marshes than oligohaline marshes. Brown shrimp, the most abundant penaeid, were prevalent in polyhaline areas of the bay. (Fig. 7).

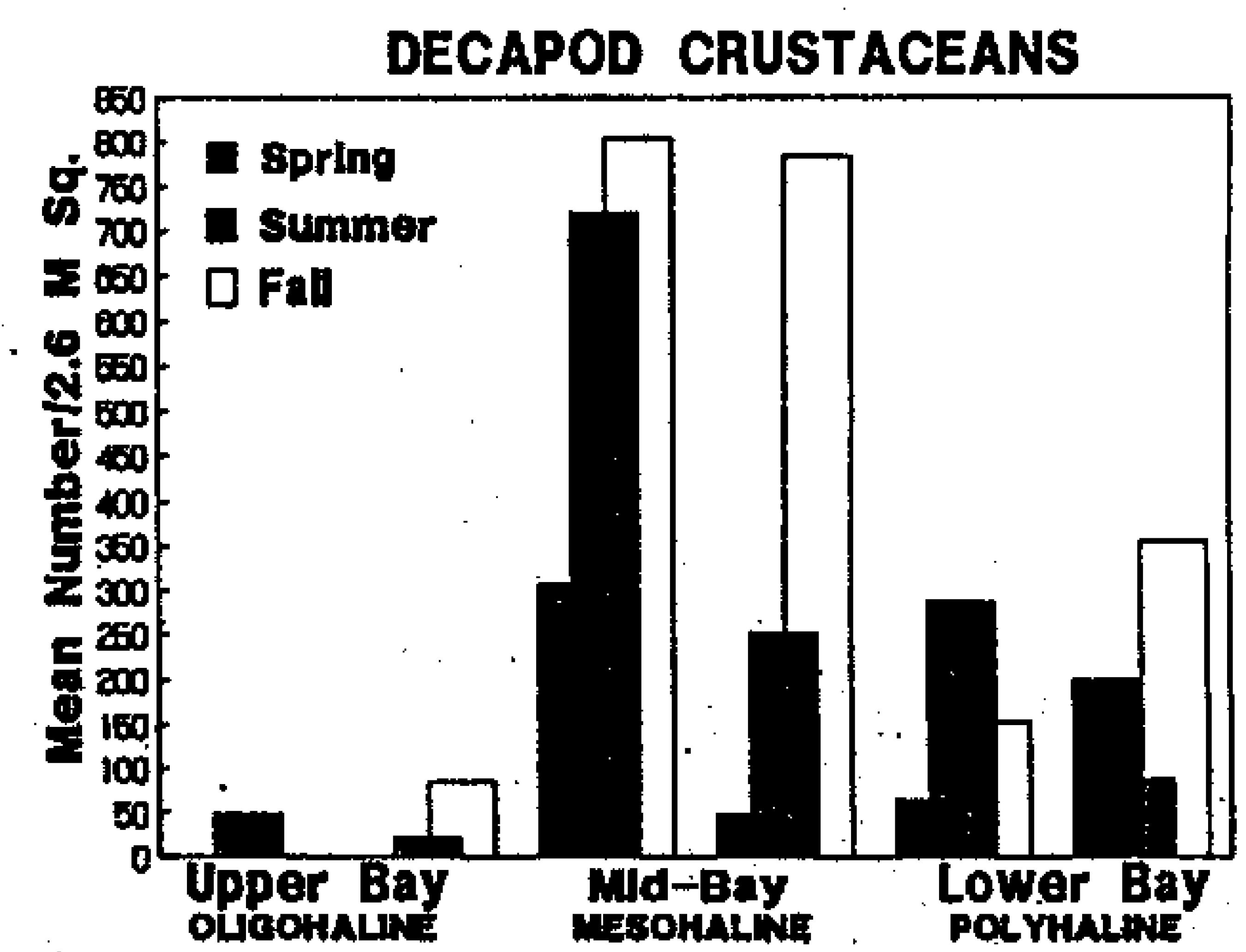

Figure 6. Densities of decapod crustaceans in marshes along the salinity gradient in Galveston Bay during spring, summer and fall seasons of 1987.

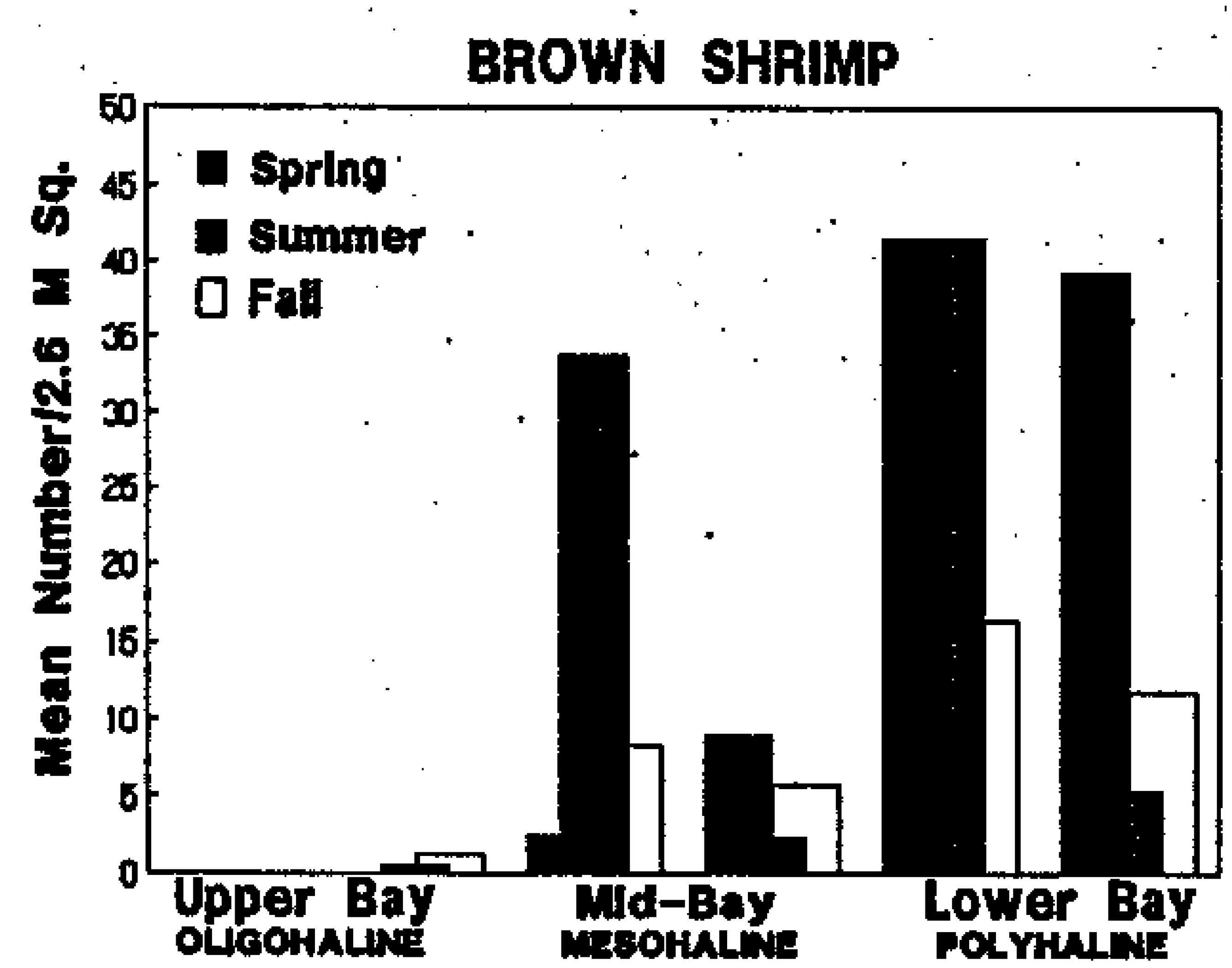

Figure 7. Densities of brown shrimp in marshes along the salinity gradient in Galveston Bay during spring, summer and fall seasons of 1987.

Discussion

Estuarine marshes are valuable habitats that can be used as nurseries by fishery species. Evidence for direct use of marsh surfaces by juvenile penaeid shrimps and commercial fishes is available from estuaries both on the U. S. eastern coast (Weinstein 1979; Hettler 1989) and in the Gulf of Mexico (Zimmerman and Minello 1984; Rozas 1992). Marshes are used by transient juveniles of fishery species because of increased habitat cover and food value (Boesch and Turner 1984; Minello and Zimmerman 1991).

The use of marshes by fishery species extends throughout the estuarine gradient from saline marshes near the coast to intermediate and freshwater marshes in riverine delta areas. The degree of use varies dependent upon species and salinity structure. Low salinity Georgia marshes have been characterized as nursery areas for Atlantic croaker, southern flounder, silver perch, hogchoker and spot (Rogers et al. 1984). In Virginia, tidal freshwater marshes were used by killifishes and blue crabs (Rozas and Odum 1987). Low salinity delta habitats in coastal Louisiana are extensively used by Gulf menhaden, Atlantic croaker and bay anchovy (Deegan and Thompson 1985). Brown shrimp, white shrimp and blue crab generally use intermediate and saline marshes (Zimmerman and Minello 1984; Hettler 1989; Mense and Wenner 1989; Kneib 1991; Rozas 1992).

In our studies, marshes under persistent oligohaline conditions, were little used as nursery habitat by fishery species. Densities of juveniles of penaeid shrimps, spotted seatrout, southern flounder and red drum were more than an order of magnitude less in upper bays with extended periods of salinities below 5 ppt. Deegan and Thompson (1985) also reported a positive relationship between standing crop of estuarine fishes and apparent salinity among three estuaries of the Mississippi delta. Importantly, our highest faunal densities occurred in mesohaline marshes with salinities ranging between 5 to 18 ppt. Polyhaline marshes (18 to 30 ppt) had relatively lower densities but greater diversity of fishery species compared to mesohaline marshes. For some important species, such as brown shrimp, densities were consistently higher in polyhaline marshes. All of these data indicate that oligohaline conditions limit and diminish the use of marshes as nurseries for estuarine dependent fisheries.

The three Texas bays exemplified how marsh use by fishery species is affected by watershed characteristics. Accessibility of marshes by estuarine fauna is highly dependent on salinity and the factors that affect salinity structure in an estuary. Large bays with large watersheds , high river inflow, and a large inlet from marine waters usually have a persistent salinity gradient. As in Galveston Bay, these estuaries have large relatively stable mesohaline zones. It is this mesohaline zone that has the greatest potential for high production from fishery species, both from utilization of marshes and open water habitats. Mesohaline and polyhaline marshes of the middle and lower parts of Galveston Bay were continuously used by fishery juveniles, whereas the oligohaline marshes of the upper bay were only intermittently used. During periods of high or low rainfall, the mesohaline zone may be translocated but it is rarely if ever eliminated in such large bays. By comparison, marsh use in small bays with large watersheds is highly variable and negatively affected by high river inflow. In San Antonio Bay, high rainfall often caused the salinity gradient in the bay to be virtually eliminated. Marsh use by most of the fishery species in San Antonio Bay was inversely related to the river flow and directly related to salinity. Gulf menhaden was the only exception where utilization was directly related to river flow. Lavaca Bay was also a small bay but possessed a small watershed. A dam situated about 10 km above the river mouth further restricted river inflow. High salinities in this bay often extended onto the delta and high rainfall periods had little lasting effect on lowering the salinity. The fishery species in Lavaca Bay used marshes throughout the bay, including those of the delta. In this bay, the mesohaline zone was often restricted to the upper bay and delta area and most of the bay was polyhaline. In all of the bays, extended intervals of mesohaline and polyhaline salinities promoted the use of marshes by fishery animals. Persistent oligohaline conditions, on the other hand, depressed marsh use by fishery species in all three systems. We conclude that fishery production is least stable in small bays with large watersheds and that large bays with large mesohaline zones are most productive.

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